System Synthesis Models as a Standard DoD Tool for Automatic Test System Analysis, Selection, and Development

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Abstract - ***System Synthesis Models (SSM+), a critical part of the Consolidated Automated Support System (CASS) Introduction Planning Process, is also used as a valuable decision support tool in the Automatic Test System (ATS) Selection Process. SSM+ is used to identify the limitations of various candidate ATS for supporting a weapons system platform or set of Units-Under-Test (UUTs). SSM+ can be used to identify potential ATS product improvement efforts and to assist in the development of Reconfigured or Downsized ATS stations. A potential application of SSM+ addressed herein is the assignment of UUTs to Operational Test Program Set (OTPS) groups based on common mechanical interface requirements and exceptions as well as the development of a Family of Common Interface Devices. Although only military examples are discussed herein, SSM+ would have similar potential applications in the commercial world.***

INTRODUCTION

The System Synthesis Model (SSM), purchased from General Electric under the original CASS contract, was redesigned by NAWCAD Lakehurst into SSM+ as an automated decision support tool to help determine the optimum quantities and configurations of CASS stations required to support a platform's UUT testing requirements. SSM+ consists of an Oracle database which has evolved into an integral part of the CASS Implementation Planning process, providing a UUT to CASS Mapping Model and Site Workload Models.

With the establishment of the DoD Automatic Test System Executive Agent Office (ATS EAO) in 1995, SSM+ has become the single recognized automated tool for mapping a weapon system's UUT test requirements to ATS within the DoD Family of Testers. The current DoD ATS policy dictates that all DoD components shall satisfy all acquisition needs for Automatic Test Equipment (ATE) hardware and software by using designated ATS Families, with the Army's Integrated Family of Test Equipment (IFTE) and the Navy's CASS, being the initial designated DoD ATS Families. With the parametric test capabilities of CASS and IFTE stored into the SSM+ database, a weapon system's UUT test requirements can efficiently be mapped to CASS, IFTE, or any other ATS whose characteristics are loaded into the SSM+ database.

Limitations of the various ATS to provide full support to the weapon system are identified as exceptions. An engineering analysis of the exceptions can then be performed to assess the severity of ATS limitations for supporting that weapon system. Exceptions can be categorized as soft, medium, or hard. Soft exceptions are those exceptions considered negligible in which little or no Interface Device/Test Program Set (ID/TPS) intervention would be anticipated to satisfactorily test the UUT. Minor ID/TPS intervention, such as incorporating passive or simple active circuitry into the ID, would be anticipated to overcome medium exceptions. Complex ID/TPS intervention would be anticipated to overcome hard exceptions. Complex intervention would include the requirement to build complex active circuitry into the ID or to incorporate the use of external test equipment into the execution of the TPS.

In addition to facilitating the DoD ATS Selection process, SSM+ is also utilized to identify potential CASS Pre-Planned Product Improvement (P^3I) efforts in support of the CASS Program Office. In the past, SSM+ has also been used to identify possible Reconfigured CASS Stations that could be designed with only a limited number of CASS assets required to optimize CASS support of various platforms within space constrained environments. Potential DoD wide and commercial applications of SSM+ include the following:

- Identifying potential product improvement efforts for ATS in the approved DoD Family of Testers.
- Identifying and developing reconfigured versions of approved ATS to meet mission requirements with severe space constraints and/or requiring only limited capability.
- Identifying a logical set of OTPS groups for a set of UUTs based on common exceptions.

- Identifying and developing a family of Common Interface Devices (CIDs) by categorizing recurring "exceptions" which for one reason or another do not warrant product improvement efforts to the DoD Family of Testers.
- Modeling Commercial Off-the-Shelf (COTS) ATS, providing an ATS Selection tool which can be utilized by private industry to evaluate commercial test requirements.

SSM+ AND THE CIP PROCESS

SSM+ is an integral part of the CASS Implementation Planning (CIP) Process, an on-going effort to assure the timely introduction of CASS to support emerging weapon systems and the coordinated offload of currently fielded TPSs to CASS. SSM+ is the primary instrument in the CIP Process used to determine the quantity and configuration mix of stations needed to support all planned testing at each intermediate or depot level maintenance site.

Although a maintenance site may support multiple platforms, each platform does not necessarily require a dedicated CASS station. The library of parametric testing requirements for each Navy UUT and CASS workload data contained in SSM+ allows for the creation of station sharing arrangements at each site. Parametric test requirement data is used to identify what CASS configuration is required to support each UUT while CASS workload data is used to determine station loading requirements. CASS workload data consists of CASS operational availability, a site's operational hours, TPS delivery dates, elapsed maintenance times for UUT repair on CASS, and weapons system component induction rates.

SSM+ has proven itself to be an invaluable tool, allowing the CIP Team to have CASS in place at TPS developer and fleet sites on time and with the optimal station mix to support the full aircraft or ship component workload across all programs.

SSM+ FOR ATS SELECTION

Many factors must be considered when choosing the right ATS for support of a weapons systems platform. Operational suitability, Integrated Logistic Support (ILS), TPS transportability, and cost are just a few of the issues which must be thoroughly investigated during the ATS Selection Process. The first step, however, should be to ensure that all of the candidate ATS have sufficient test capability to satisfy the test requirements of the weapons system under consideration. SSM+ provides an automated means to quickly compare UUT test requirements to ATS test capabilities and has been selected by the DoD ATS EAO as the single automated tool for storing UUT test requirements and ATE test capabilities.

While SSM+ provides a fast and efficient means of mapping UUT test requirements to ATS capabilities, a manual engineering analysis is nonetheless required to evaluate the results from SSM+, particularly exception reports. SSM+ exception reports identify limitations of the ATS under consideration for providing full support to the weapons systems platform. This does not mean that the ATS cannot support the weapons system, but that the capabilities of the ATE may have to be supplemented through the use of complex IDs, external test equipment, and/or other TPS intervention.

It would be unrealistic to design an ATS that could fully support a complex weapons system composed of a wide variety of complicated UUTs. The resultant ATS would be a large, expensive system which incorporates a variety of exotic instruments needed to test only a small percentage of the target UUT population.

Figure 1 identifies an ATS Selection Process based on automated SSM+ capabilities and manual engineering analysis of SSM+ exception reports. Evaluation of exception reports for a set of UUTs against a piece of ATE provides a valuable assessment of how well that ATE will support the UUTs. Comparing how well UUTs test requirements stack up against several candidate ATE provides a good start in the ATS selection process.

Using SSM+, test requirements for a set of UUTs are mapped against the capabilities of the candidate ATS. Limitations of the ATS are identified as exception reports which can be printed out for review. Grouping exceptions by test category will often greatly assist in the evaluation process. In evaluating exception reports, each exception can be categorized into one of the following categories:

- ***Soft Exception***: Considered negligible; No interface device (ID)/Test Program Set (TPS) intervention anticipated (small differences in accuracy)

- ***Medium Exception***: Minor ID/TPS intervention is anticipated to overcome the limitations of the ATS (voltage dividers, simple or common circuit cards, etc.)
- ***Hard Exception***: Complex ID/TPS intervention is anticipated to overcome ATS limitations (complex or peculiar circuit cards in the ID or the use of external test equipment may be required)

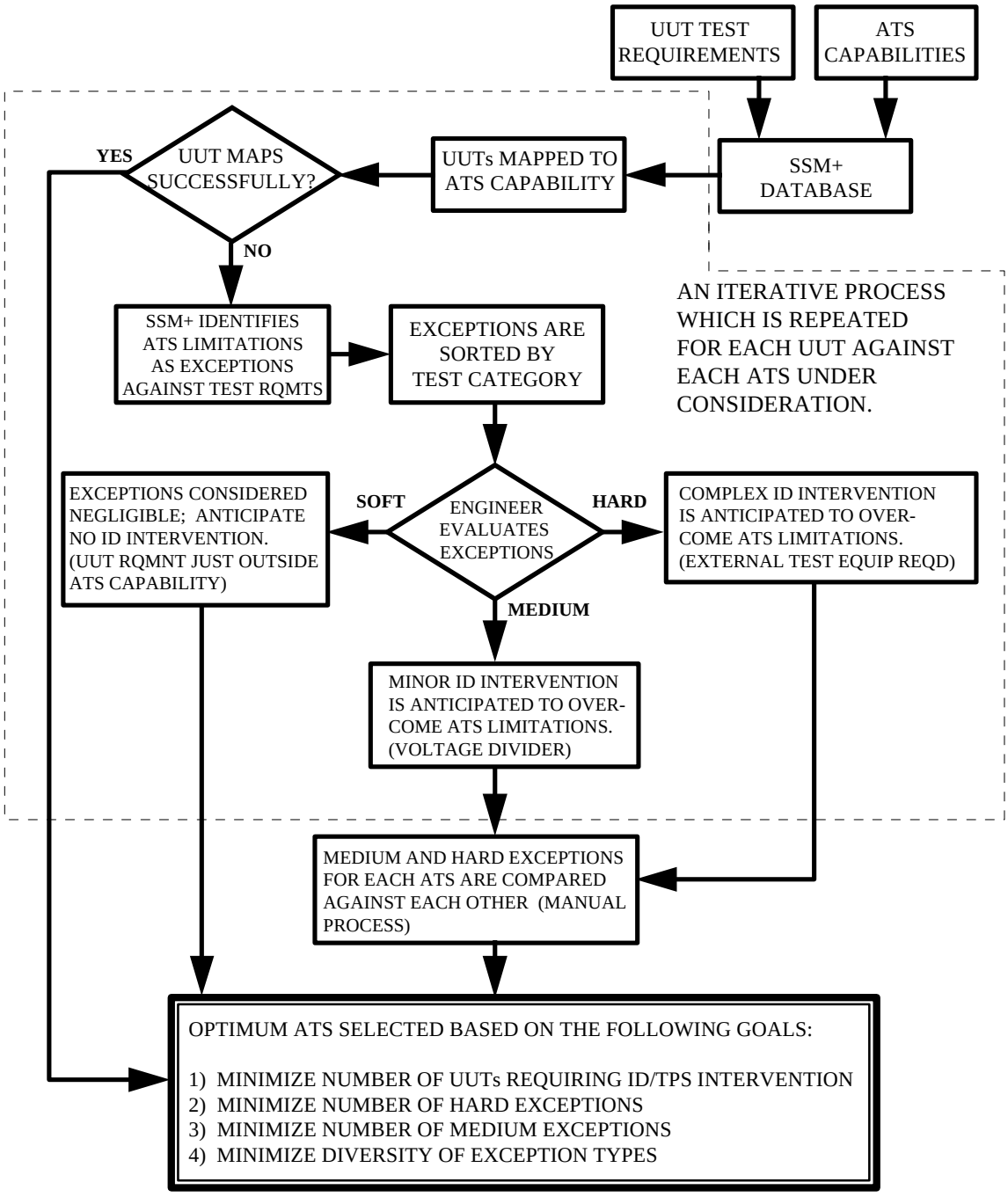

Figure 1. ATS Selection by SSM+ Exception Analysis

Table 1 provides an example of a UUT DC power supply test requirement versus the ATS test capability to illustrate how exceptions may be analyzed and classified.

Table 1. Exception Classification Against a UUT DC Power Test Requirement

TEST PARAMETER	ATS CAPABILITY	UUT TEST RQMNT	EXCEPTION CLASS
Voltage	100 V	150 V	MEDIUM
Voltage Tolerance	± 0.5 V	± 0.45 V	SOFT
Maximum Current	8 A	4 A	NOT EXCEPTION
Maximum Ripple	0.075 V	0.15 V	NOT EXCEPTION

In this example, the maximum current and ripple required by the UUT are within the capabilities of the ATS and are consequently not exceptions. The UUT's voltage tolerance requirement is flagged by SSM+ as an exception because it is below the specified capability of the ATS power supply. However, because the ATS provides a better overall combination of tolerance and ripple (± 0.575 V) than required by the UUT (± 0.60 V), this exception is classified as ***soft***. The UUT DC voltage requirement is also flagged by SSM+ as an exception as it is greater than the capability provided by the ATS. This is classified as a ***medium*** exception because the ATS can provide more overall power (800 Watts) than required by the UUT (600 Watts) and a DC to DC converter can be built into the ID to step up the voltage. If the UUT had a requirement of 150 VDC at 6 amps (900 Watts), then this exception would be classified as ***hard*** because an external power source may be required.

Although exception report analysis can often prove to be a difficult and time-consuming task, it is necessary to accurately assess the capabilities of the various ATS for supporting the set of UUTs. While 30 exceptions may exist against ATS "A" and only 10 exceptions against ATS "B", exception analysis could show that ATS "A" would better support the weapons systems platform. Twenty-five (25) soft exceptions against ATS "A" may prove to be non-players during the TPS Development Process while five (5) medium exceptions may result in some minor ID intervention. If the ten (10) exceptions against ATS "B" are categorized as hard, complex and costly IDs and/or external test equipment may be required to fully support the weapons system and ATS "A" would be the better option.

In performing exception analysis and categorizing exceptions, one must distinguish between the conditions of an ideal world and the considerations that must be made in the real world. Key differences are as follows:

IDEAL WORLD

- All test requirements are accurate and true.
- Exceptions translate to single, unique solutions.
- No logistics considerations.

REAL WORLD

- Test requirements based on interpretation and subject to change.
- Different TPS Developers will provide different solutions.
- Logistics and life cycle costs are crucial factors in determining UUT support strategy.

Once all exceptions have been reviewed and categorized against each ATS, the optimum ATS can be selected by trying to minimize the following:

- **Number of UUTs requiring ID/TPS Intervention** - 50 exceptions against 5 UUTs may prove more desirable than 20 exceptions against 10 UUTs.
- **Number of Hard Exceptions** - Hard exceptions would typically result in costly TPS development efforts
- **Number of Medium Exceptions** - Medium exceptions may increase TPS development costs
- **Diversity of Exception Types** - Numerous exceptions of one type may require only one complex ID while several different exception types may drive several complex IDs

It should be noted that the above does not necessarily reflect the order of priority as each case brings unique considerations to the table. Also, as previously discussed, this analysis is based solely on an objective comparison of UUT test requirements versus ATS capabilities and numerous other factors may be involved in the ATS selection process.

IDENTIFYING CASS P^3I EFFORTS WITH SSM+

SSM+ exception analysis has also been utilized to identify potential CASS P^3I efforts to the Navy's CASS Technical Working Group (TWG). Queries of the SSM+ database were performed to compare the parametric test requirements of new and offload Navy UUT's to the test capabilities of CASS. Because all test requirement data is stored by test categories, test requirements outside the range of any given CASS test capability can quickly and easily be identified.

Queries can further be executed to determine if test requirements not satisfied by CASS are isolated to a small group of UUTs or are distributed throughout the entire UUT population. Those exceptions common to numerous UUTs and across multiple platforms are prime candidates for P^3I investigations. Exception analysis of test requirements in the Resistive Load Test Category, for example, indicate a trend towards loads with lower ohmic values, tighter accuracies and higher power dissipation rates and indicate a possible need for an additional electronic load bank in CASS.

One must realize that not all common exceptions will warrant P^3I efforts, as ID intervention to overcome these exceptions may be trivial and far less costly than a change to CASS. Exceptions in the Complex Waveform Test Category resulting from requirements to measure signal amplitudes above the Waveform Digitizer's capability can easily be overcome with the incorporation of a voltage attenuator in the interface device.

SSM+ CASS ASSET TO UUT MATRICES

In order to facilitate various studies regarding a potential "Downsized" or "Reconfigured" CASS Test System, Naval Air Warfare Center Aircraft Division Lakehurst developed the "CASS Asset to UUT Matrix" SSM+ mapping report. SSM+ provides this report as a flat file which can be opened in Microsoft Excel, allowing the user to easily sort and analyze the output data. Figure 2 provides an example of a SSM+ CASS Asset to UUT Matrix in Excel format. Although this "Asset to UUT Matrix" has only been developed for CASS, this report can be modified for any ATS modeled in SSM+.

For a given set of UUTs, this report identifies all CASS assets (digital multimeter, pulse generator, etc.) required to test each UUT. CASS assets are identified across the top of the matrix while individual UUTs are listed down the left side. This report also identifies the number of exceptions against each UUT and the CASS assets which the exceptions are against. Although an exception indicates that no CASS asset can completely satisfy a given test requirement, SSM+ can still identify the "closest" CASS asset which best fits the test requirement. While CASS does not have a DC power supply capable of providing 110 VDC at 6 amps, the 100 VDC power supply would be identified as the best fit or "closest" CASS asset. This CASS power supply could provide 100 VDC at slightly more than 6.6 amps to a DC voltage converter in the interface device which could in turn provide 110 VDC at 6.0 amps to the UUT.

CASS assets required to test each UUT are identified in the matrix with a set of two (2) numbers, X/Y. "X" represents the number of UUT test requirements entered into SSM+ which successfully map to that CASS asset while "Y" indicates the number of test requirements mapping to that CASS asset with exception. In Figure 2, for example, the "12\2" in the arbitrary waveform generator (AWG) column against the engine monitoring unit, part number 56789, indicates that twelve (12) test requirements of the engine monitoring unit can be satisfied by the CASS AWG, while two (2) test requirements map to the CASS AWG with exception. Solutions to these exceptions may require adding a simple operational amplifier circuit to the interface device to increase the voltage swing of the CASS AWG output or can involve much more complex circuitry to shift the AWG's output frequency.

This matrix allows one to identify possible reconfigured CASS stations that could be designed with only a limited number of assets to optimize CASS support of a platform within a space constrained environment. Figure 2 identifies six (6) core assets which are required to test at least 50% of the platform's UUTs. The matrix is sorted such that the addition of each new asset to the "Core Tester" allows for the testing of additional UUTs. While five (5) racks of test assets may be required to test a platform's full suite of UUTs, four (4) racks may provide enough capability to test 95% of the platform's UUTs and three (3) racks enough capability to test 90% of the UUTs. Depending on the severity of space or even cost constraints, the optimum solution may be to procure a three (3) rack test station and support only 90% of the UUTs.

			CORE ASSETS															
UUT NOMENCLATURE	UUT P/N	QTY OF EXCEPTS	32 VDC PWR SPLY	DIGITAL MULTI-METER	DIGITAL TEST UNIT	WAVE-FORM DIGIT	ARB WFRM GEN	135 VAC PWR SPLY	MIL-STD 1553 BUS	IEEE 488 BUS	100 VDC PWR SPLY	FREQ/ TIME INT CNTR	PWR LOADS	RF GEN	RF POWER METER	SPECT ALYZR	EO TEST UNIT	TOTAL TEST RQMNTS
POWER SUPPLY ASSEMBLY	12345	0	2\0	4\0	4\0	2\0	5\0											17\0
SWITCHING UNIT	23456	0	2\0	4\0	2\0		4\0											12\0
CSU SUSCRIBR CARD	34567	1	3\1	3\0	2\0	1\0	5\0	1\0										15\1
DATA STORAGE UNIT	45678	1	4\0	3\0	1\1	1\0	6\0											15\1
ENGINE MONITORING UNIT	56789	2	2\0	10\0	3\0	12\0	12\2		2\0									41\2
COXKPIT INTERFACE UNIT	67890	2	1\1	12\1		5\0	4\0	1\0	1\0	1\0								25\2
LANDING GEAR CONTROL UNIT	78901	0	2\0	4\0	1\0			1\0		2\0								10\0
ENVIRONMENTAL CTRL UNIT	89012	1	2\0	5\1	1\0	2\0			2\0	2\0								14\1
PROCESSOR UNIT	90123	0	2\0	12\0	1\0	1\0		1\0			1\0							18\0
SIGNAL DATA CONVERTER	A1234	0	2\0	22\0	2\0				3\0		2\0							31\0
SIGNAL DATA PROCESSOR	B1234	3	3\1	4\0	3\1		1\0			4\0		3\1						18\3
ENCODER/DECODER	C1234	0	2\0	3\0	1\0	5\0	4\0	1\0	2\0		2\0	3\0						23\0
TEMPERATURE CONTROL	D1234	0	2\0	3\0	5\0	20\0		6\0				4\0						40\0
POWER SUPPLY	E1234	2	2\2	10\0	4\0	1\0		1\0		5\0			4\0					27\2
SERVO CONTROLLER	F1234	3	2\0	12\1	1\1				2\0				2\1					19\3
DATA BUS INTERFACE UNIT	G1234	0		4\0	12\0	4\0		2\0	2\0	2\0	4\0	3\0	5\0					38\0
ROLL-PITCH-YAW COMPUTER	H1234	0	2\0	3\0		1\0			4\0	2\0			6\0					18\0
TRANSMITTER	J1234	2	2\0	3\0	2\0	4\0	6\2	1\0	4\0	2\0				6\0		2\0		32\2
RECEIVER	K1234	0	2\0	10\0			1\0	1\0			4\0	4\0			6\0	5\0		33\0
FLIR UNIT	L1234	2	2\0	12\1	15\1	1\0	1\0										2\0	33\2
TOTAL TEST RQMNTS MAPPED TO CASS ASSET			41\5	143\4	60\4	60\0	49\4	16\0	22\0	20\0	13\0	17\1	17\1	6\0	6\0	7\0	2\0	
TOTAL UUTS MAPPED TO CASS ASSET			19	20	17	14	11	10	9	8	5	5	4	1	1	2	1	
TOTAL UUTS			20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	
PERCENT UUTS MAPPED TO CASS ASSET			95.0	100.0	85.0	70.0	55.0	50.0	45.0	40.0	25.0	25.0	20.0	5.0	5.0	10.0	5.0	
% OF TEST RQMTS MAPPED SUCCESSFULLY			89.1	97.3	93.8	100.0	92.5	100.0	100.0	100.0	100.0	94.4	94.4	100.0	100.0	100.0	100.0	

Figure 2. Sample SSM+ CASS Asset to Unit-Under-Test Matrix

One must remember to consider all engineering and logistics issues when identifying a "downsized" or "reconfigured" test station. If the 10% of the platform's UUTs which can not be supported by the three (3) rack configuration represent the platform's high failure/high cost items, then this configuration may not be the most economical solution. There may, however, be a 3 rack solution which supports these high failure/high cost UUTs but only supports 75% of the platform's overall suite of UUTs. If only low failure/low cost UUTs fall into the 25% which can not be supported by the new 3 rack configuration, then perhaps this configuration would represent the optimum solution.

To date this matrix has been primarily used to identify possible reconfigured CASS stations for various applications. However, because this matrix provides a quick and easy way of looking at a platform's entire support requirement, additional applications of this matrix exist.

The bottom two (2) rows of the matrix identify the percentage of UUTs mapped to each CASS asset and the percentage of test requirements mapped successfully to each asset. A CASS asset which maps to a large percentage of UUTs would likely have a high utilization rate while a CASS asset mapping to a small percentage of UUTs may have a much lower utilization rate. This information could be used to help determine or adjust CASS spares requirements, allowing for the optimization of CASS spares to the mission of a given CASS station. A low percentage of test requirements which successfully map to an asset could indicate a large number of exceptions against that asset. Further investigation may reveal that a product improvement effort is warranted to minimize the requirement for complex IDs in the field and to keep CASS test capabilities current with test requirements for new UUTs being introduced to the fleet. However, further investigation may reveal that this large percentage of exceptions results from a peculiar test requirement common only to UUTs on a single platform. In this instance, it may make more sense to provide the additional required test capability through ancillary equipment used only with OTPSs for that platform.

While CASS was applied to all examples provided herein, these SSM+ applications can be applied to any ATS modeled in the SSM+ database by developing the appropriate "ATS Asset to UUT Matrix" report capability.

USING SSM+ FOR OTPS GROUPING

One potential application of SSM+ is as a tool to identify logical OTPS groupings and for identifying a set of Common Interface Devices. SSM+ provides an extensive database for storing UUT electrical test requirements and a valuable tool for identifying ATS limitations to satisfy these requirements as exceptions. By grouping like exceptions, SSM+ could identify UUTs which will require similar ID intervention to overcome ATS limitations. However, differences in physical characteristics of these UUTs may prohibit grouping them on the same OTPS.

By collecting data on the required mechanical interfaces between the UUT and ATS, an automated "UUT to Mechanical Interface Matrix", similar to the existing "UUT to CASS Asset Matrix", can be developed to group mechanical requirements for interfacing each UUT with the ATS. Utilizing this matrix for a "first cut", UUTs could be grouped based on common or similar mechanical interface requirements. These OTPS groupings could be further refined using a "UUT to CASS Asset Matrix" to sort UUTs by common exceptions. Although analysis of these matrices to identify OTPS groupings would at first be a manual and iterative process done against a small population of UUTs, success in identifying logical and viable OTPS groupings could pave the way for an automated process.

A proven automated OTPS grouping process could be run against a large UUT population to identify common ID requirements across multiple platforms, setting the stage for the development of a Family of Common IDs. By optimizing the grouping of common ID requirements, smaller IDs capable of hosting more UUTs may ultimately be realized.

CONCLUSIONS

SSM+ provides a vast database for the storage of UUT test requirement and ATS test capability information and has proven to be an invaluable tool to the CASS Program. The amount and types of data contained in SSM+ make its potential applications as a tool for ATS analysis, selection, and development seem limitless. Applications of SSM+ addressed herein can be applied to any ATS that is modeled in the database and utilized by any DoD service. Similar strategies can also be utilized by the commercial sector to map commercial test requirements to Commercial-Off-The-Shelf (COTS) testers and VXI instrumentation for the design of tailored automatic test systems.

SSM+ enhancements are an on-going effort at NAWCAD Lakehurst as we strive to automate ATS analysis and selection processes as much as possible while discovering new applications for SSM+ as an ATS decision support tool. With SSM+, as with any model, the final decision is a human one and must be based on sound engineering judgment with a full understanding and appreciation of all relevant facts and issues. However, the versatility of SSM+ to quickly analyze a large repository of data allows us to make more decisions, better decisions, in less time, and with less money.

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